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Characterization of the BOLD signal in functional MRI

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Abstract

In the last two decades, functional magnetic resonance imaging (fMRI) has become an important and widely used imaging technique for functional brain mapping. However, blood oxygen level dependent (BOLD) technique is quite insensitive and task invoked BOLD signal change at 3T is typically in the order of a few percent. Furthermore, the coupling between BOLD signal changes and neuronal activities is quite complicated, involving a cascade of events remaining poorly understood even today. In this thesis, some of the basic characteristics of the BOLD signal are investigated. Better understanding of the BOLD signal characteristics can be beneficial for the design of BOLD fMRI experiment aimed to improve the time efficiency. It can also provide guidelines for developing fMRI data processing strategies.

In study I and II, a single-shot dual-echo spiral acquisition technique was used for characterizing the T_2* changes associated with motor activation task. In **study I**, the optimal strategy for head motion correction was investigated. Based on the improvement in the detection of brain activation, the best strategy is to perform the head motion correction using the imaging data from the second echo and then apply the derived motion correction parameters to the first echo, instead of conducting motion correction of the individual echoes independently. In **study II**, several aspects of brain mapping methods based on T_2*-weighted imaging and T_2* ($R_2^*=1/T_2^*$) mapping were quantitatively compared, including the detected activation volume, functional contrast, signal-to-noise ratio, and contrast-to-noise ratio. fMRI studies based T_2* mapping have the following potential advantages: maximum functional contrast, independence of echo time; and reduced inflow effects. The sensitivity for brain activation detection is significantly correlated with the contrast-to-noise ratio, which is determined by both the signal-to-noise ratio and functional contrast.

In **study III**, the hemodynamic responses to functional activation were characterized using T_2*-weighted BOLD imaging, arterial spin labeling, and bolus tracking of MRI contrast agent. In addition to the BOLD signal change, the relative cerebral blood flow and cerebral blood volume associated with brain activation were independently determined.

In **study IV**, the characteristics of the global signal in resting-state fMRI were investigated. It was found that the global signal time courses and regional contributions differ individually. However, after removing the contribution from the cerebral spinal fluid, a consistent brain network responsible for the remaining global signal changes was identified. The involved brain regions include: posterior cingulate cortex, precuneus, superior temporal gyrus, medial frontal gyrus and the cerebellar vermis, which is likely to be related to the perception and cognitive processes of the brain occurred in the specific environments during resting-state fMRI.

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